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Integrated System Test of an Airbreathing Rocket

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Rocket Based Combined Cycle Consortium (RBC^3)

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BOEING PRATT & WHITNEY AEROJET

NASA

INTEGRATED SYSTEM TEST OF AN AIRBREATHING ROCKET (ISTAR)

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Abstract

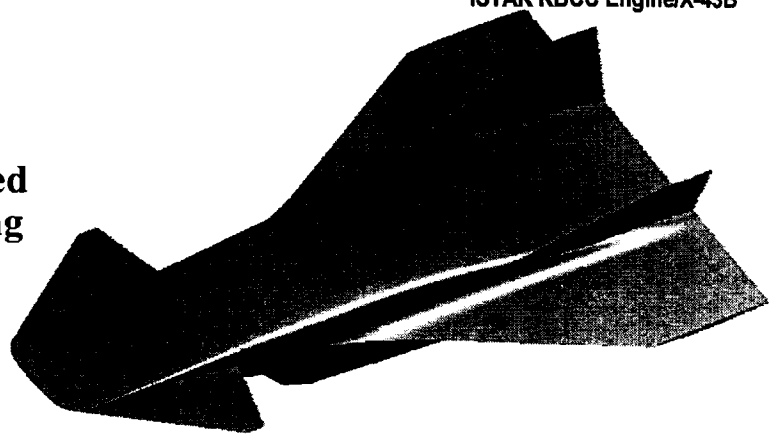
NASA is pursuing air-breathing propulsion in an effort to make future space transportation safer, more reliable and significantly less expensive than today's missions. Spacecraft powered by air-breathing rocket engines would be completely reusable, able to take off and land at airport runways and ready to fly again within days. A radical new engine project is called the Integrated System Test of an Air-breathing Rocket, or ISTAR. The flight-like engine system, called a rocket based combined cycle (RBCC), will be designed to accelerate a self-powered vehicle to more than seven times the speed of sound, demonstrating all modes of engine operation.

The development and ground test of a RBCC propulsion system is being conducted as part of the NASA Marshall Space Flight Center (MSFC) ISTAR program. Boeing - Rocketdyne, Aerojet and Pratt & Whitney have teamed as the Rocket Based Combined Cycle Consortium (RBC^3) to work the propulsion system development. Each company has complementary capabilities in the development of rocket, ramjet and scramjet propulsion systems for space launch vehicle systems. The teaming of these companies offers a unique opportunity to provide beneficial synergism by combining the best features of different approaches. The RBC^3 Team possesses the capability to perform the design, fabrication and test phases of the RBCC technology development, including flight demonstration

Introduction

The NASA Advanced Space Transportation Program (ASTP) focuses technology development in four investment areas: (1) 2nd Generation Reusable Launch Vehicle (RLV), (which is part of the national Space Launch Initiative), (2) Spaceliner (3rd Generation RLV), (3) In-Space Transfer and (4) Space Transportation Research. The goal of all four elements is to put in place a technology base, which will dramatically improve reliability, safety, operability, and reduce the cost of space access. For the 3rd Generation RLV space transportation system (contemplated for 2025 IOC), the goals are two orders of magnitude increase in safety, and two orders of magnitude decrease in operating cost, while moving toward an airline type operation. The MSFC led program, under the guidance of ASTP, has shown a significant benefit from the use of airbreathing engine technology.

ISTAR - An Introduction


ISTAR RBCC Engine/X-43B

Mission Success Criteria

- The ISTAR Ground Demonstrator Engine Project is considered successful if a rocket based combined cycle engine is ground tested and demonstrates the capability to self-power the X-43B including operation through AAR, Ramjet, and Scramjet modes (reaching approximately Mach 7)

NASA Goals Addressed

- Evaluate airbreathing propulsion technology which has the potential to reduce the cost of access to space to $100's/lb.
- Evaluate airbreathing propulsion technology which has the potential to reduce the loss of vehicle rate to 1 in a million.

Objective

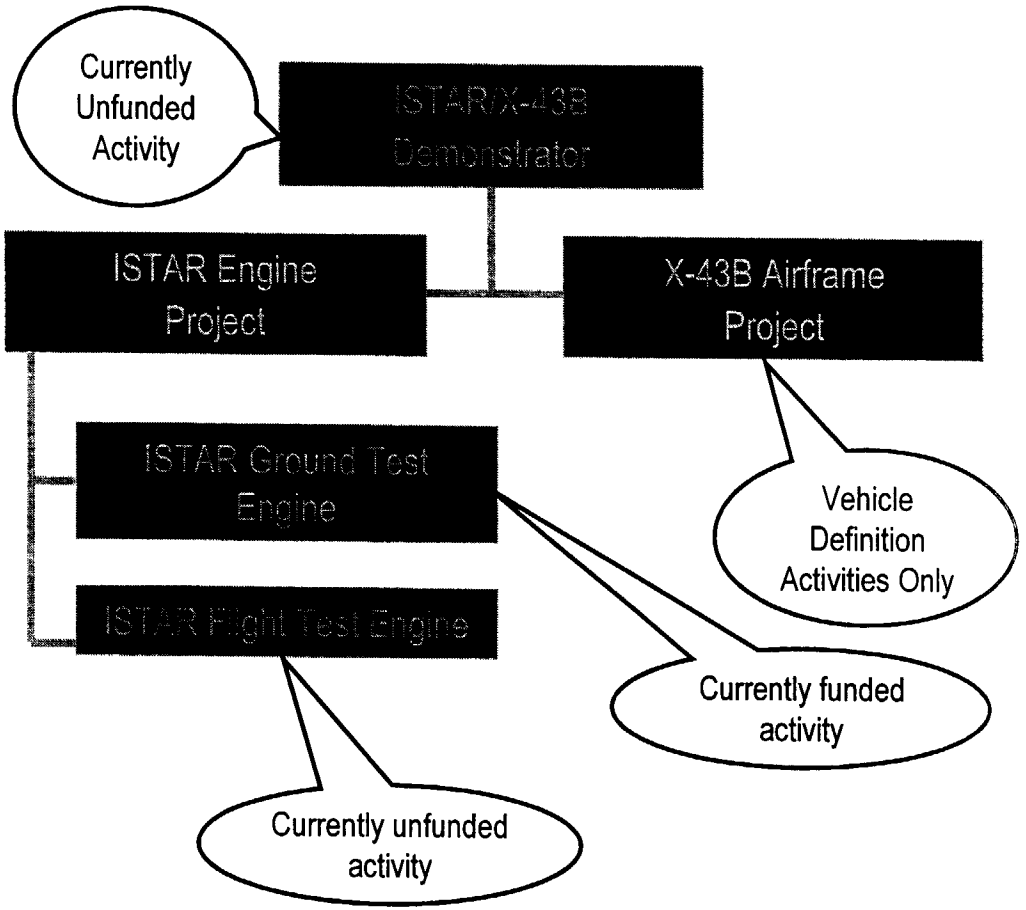
- Validate predictive capabilities including vehicle system analysis models
- Demonstrate flight weight engine system design and fabrication
- Evaluate engine system operational characteristics
- Provide testbed for evaluation of candidate innovative components

Key Features

- Designed to X-43B requirements
- Reusable system (25 missions)
- Provide for a propellant cooled, thermally and power balanced flight type engine system
- JP-7/H_2O_2

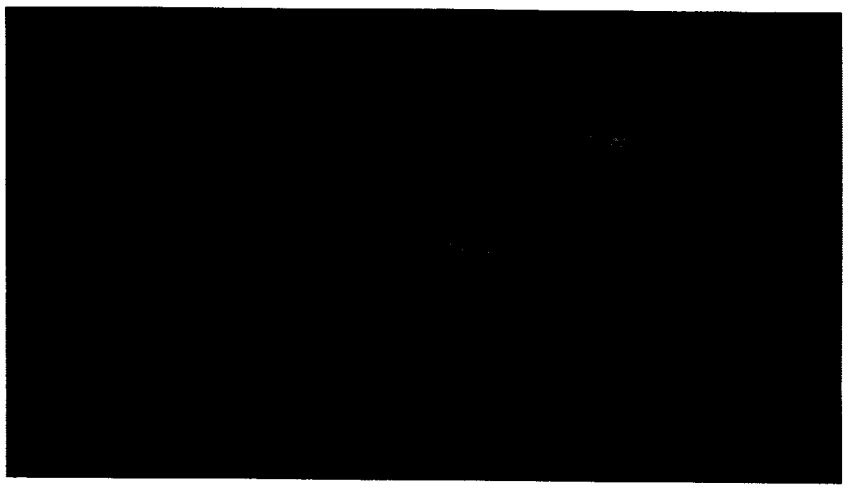
ISTAR Project Scope

- ISTAR Engine Project part of a much larger demonstrator activity
- ISTAR/X-43B – Self Propelled Flight Demonstrator M=0.7 to 7.0
  - X-43B Airframe Project – The ISTAR Project is funding limited vehicle definition activities to provide vehicle/engine requirements
  - ISTAR Engine Project – Develop RBCC engine system capable of meeting demonstrator requirements
    - Ground Test Engine
    - Flight Test Engine



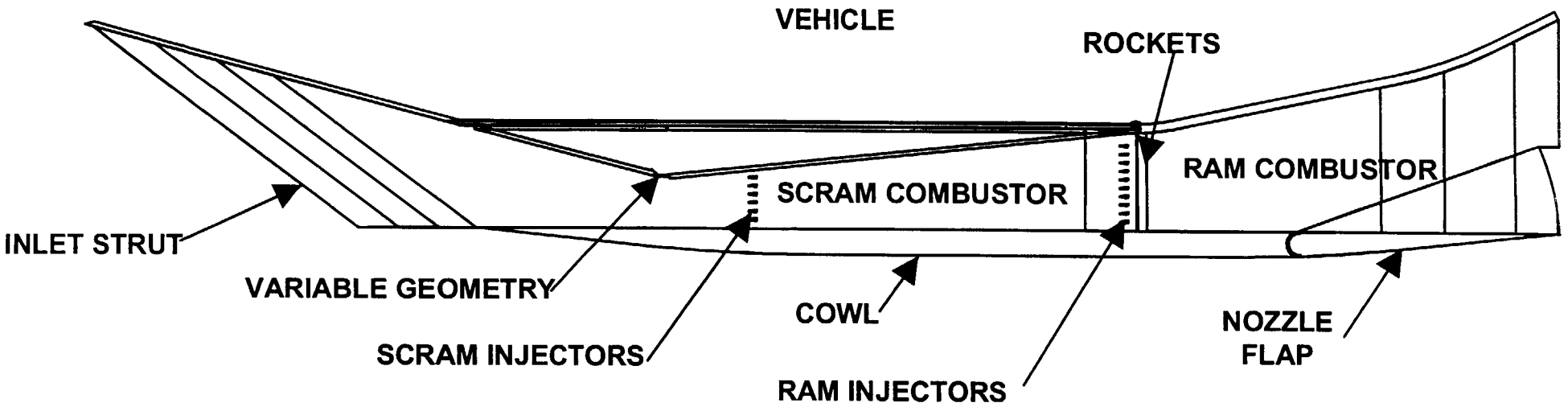
Program Deliverables

- **Phase 1**
  - Conceptual design of the FTE
  - Design Status Review Briefing/Package
  - System Requirements Review Briefing/Package
  - Data Requirement Documents such as Program Management and Risk Management Plans



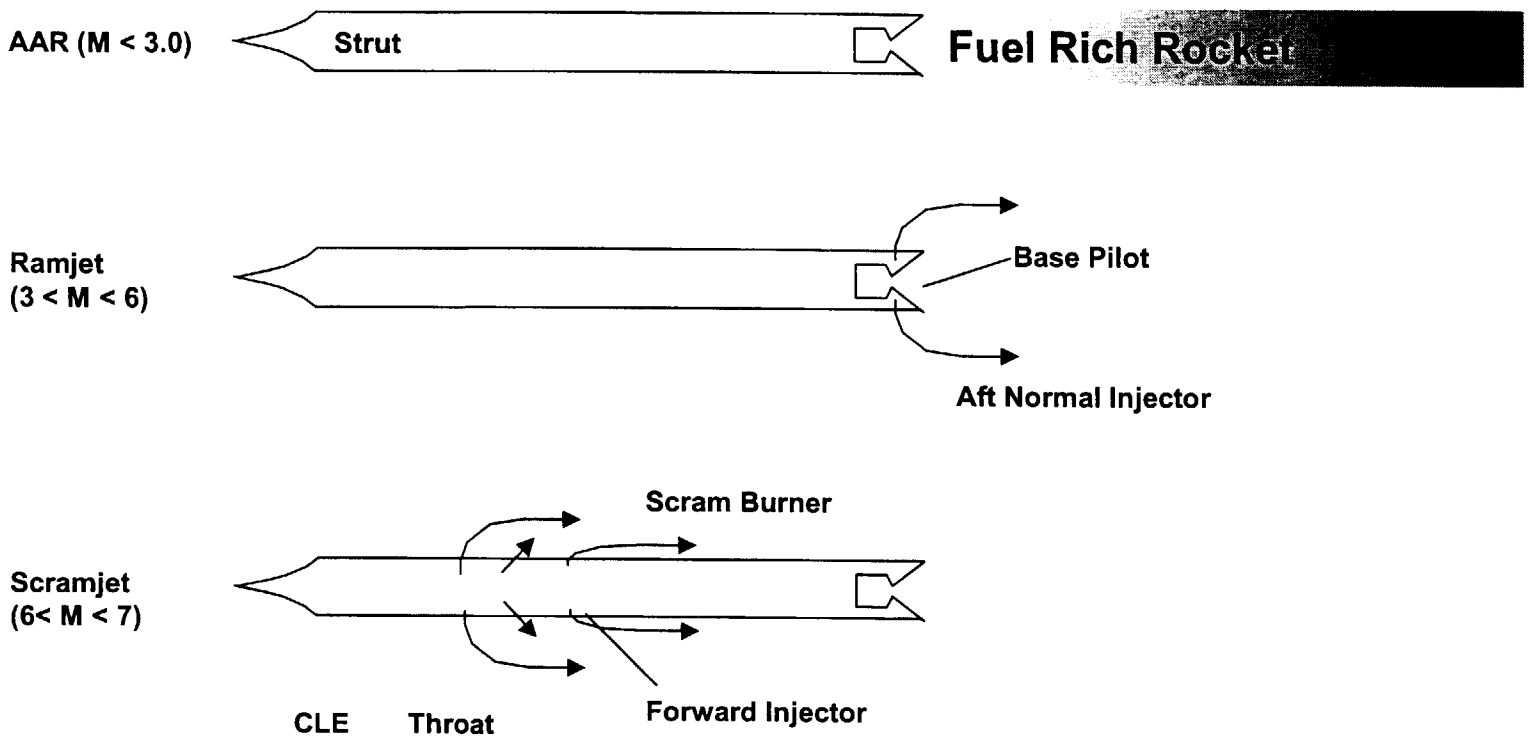
- **Phase 2**
  - Design, development and test of the GTE
  - Preliminary Design Review Briefing/Package
  - Critical Design Review Briefing/Package
  - Data Requirements Documents and updates to documents delivered in Phase 1

RBCC Reference Propulsion System



- **Several Individual Flowpaths, Each Separated by a Strut**
- **Single Engine System With Common**
  - Turbopumps
  - Propellant feed lines
  - Cooling systems
  - Engine controls

RBCC Modes of Operation



Four Primary Modes of Vision Vehicle Propulsion System

- AAR provides acceleration from air-launch through transonic
- Ramjet operation - fuel injected at the rear of struts
- Scramjet operation - fuel injected from the forward section of strut
- Rocket takeover (>M=7) - close inlet cowl and re-light rockets

Teaming Agreement

- **Industry to team to develop engine system - RBC^3**
  - Preserve U.S. high speed propulsion industrial base
  - Rocketdyne - Management Lead
  - Pratt & Whitney - Technical Lead
  - Aerojet - Systems Engineering Lead
  - FTC concurrence 8/4/00
  - Teaming agreement signed 3/19/01
- **RBC^3 activities confined to RBCC engine system development**
- **Long-term commitment - 25 years**

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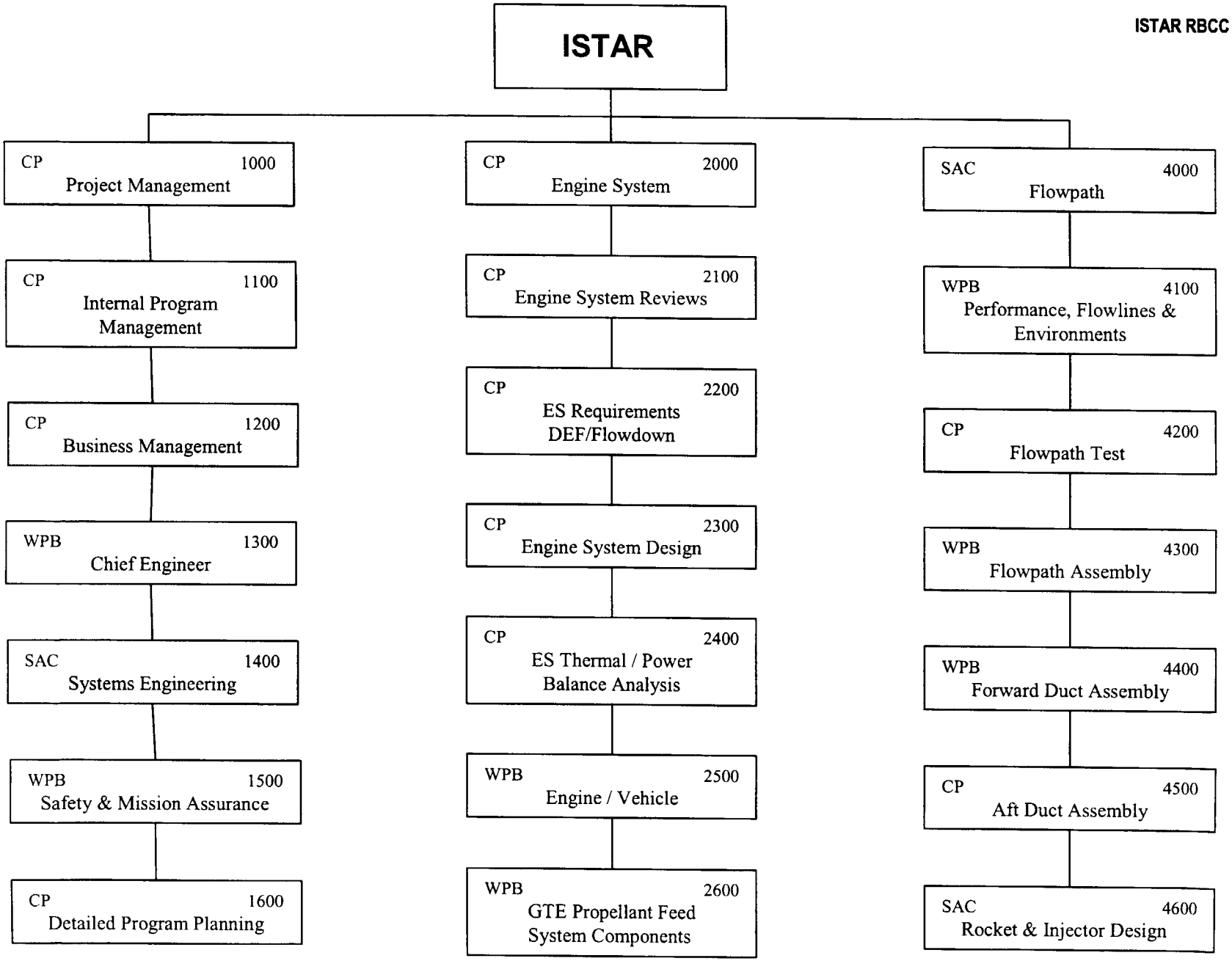
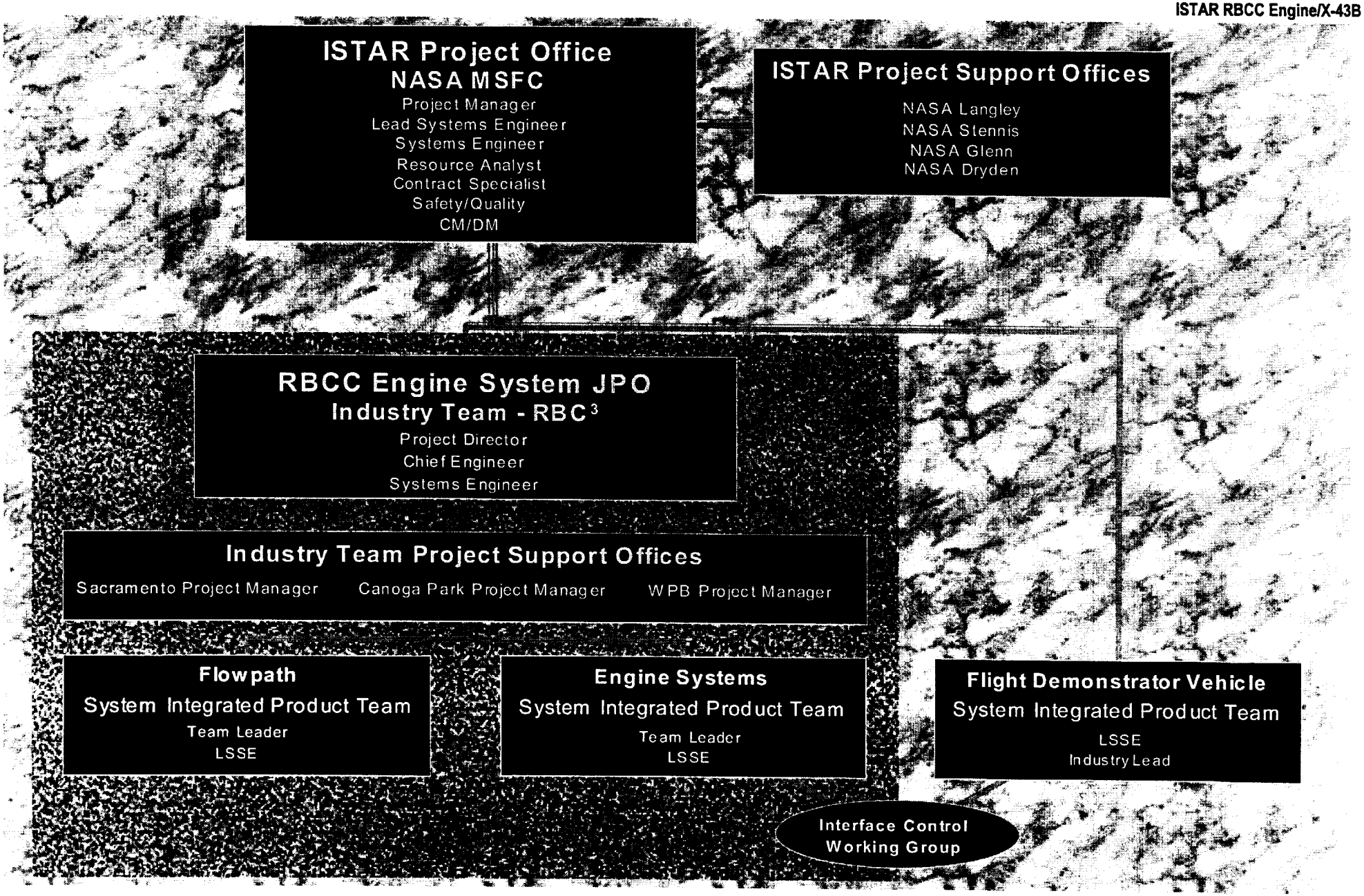
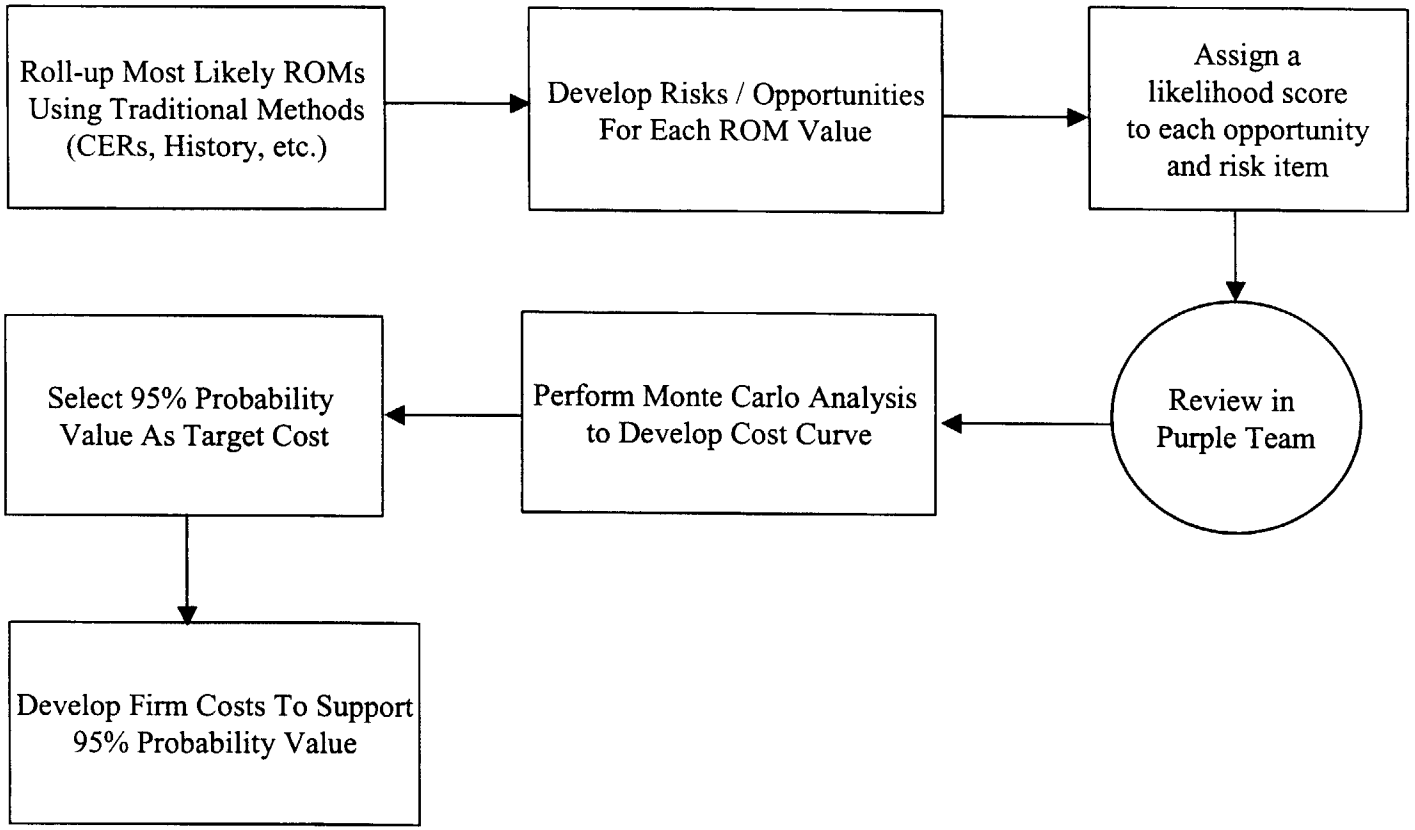
ISTAR Work Breakdown Structure



ISTAR Project Structure

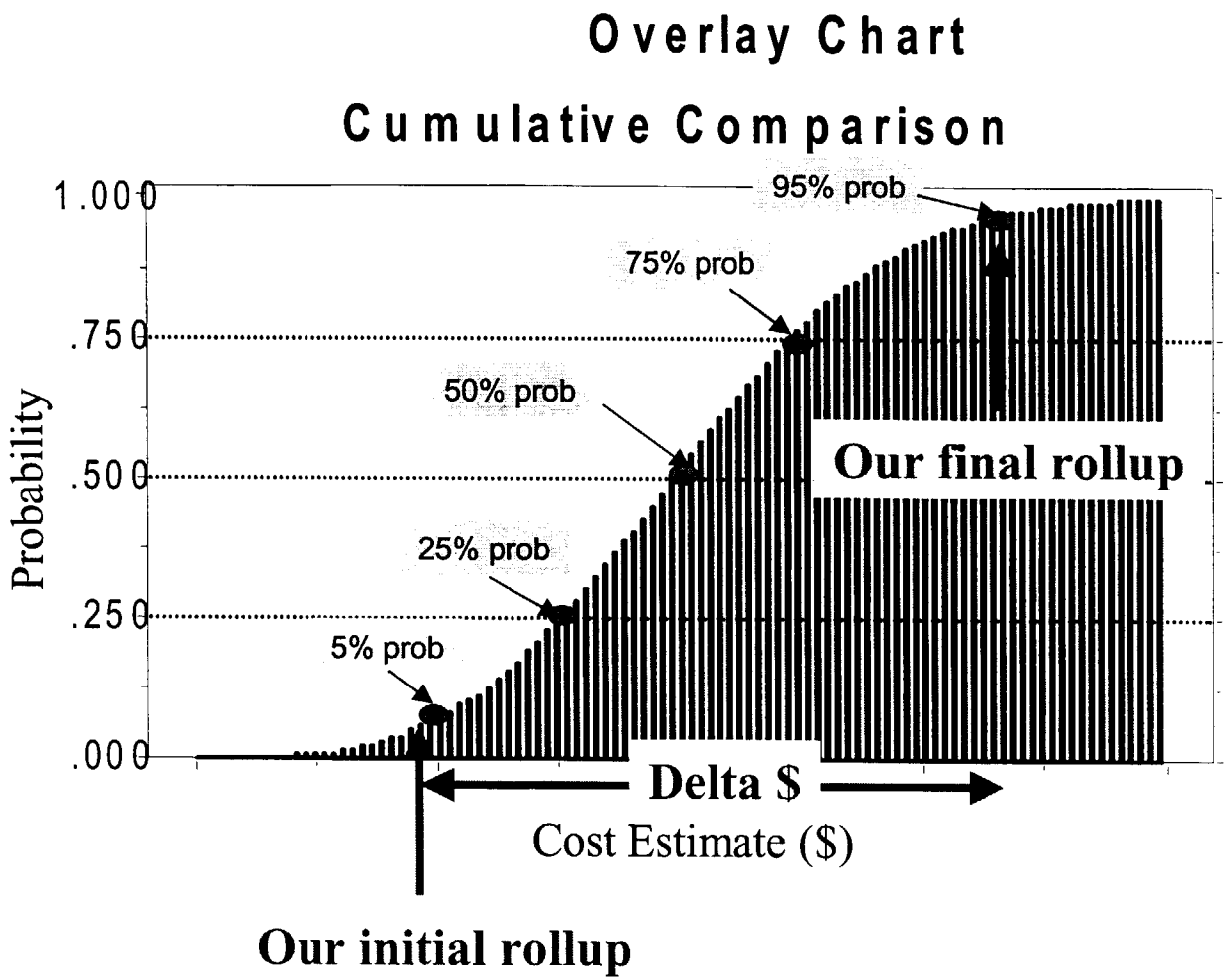


Cost Estimating Process



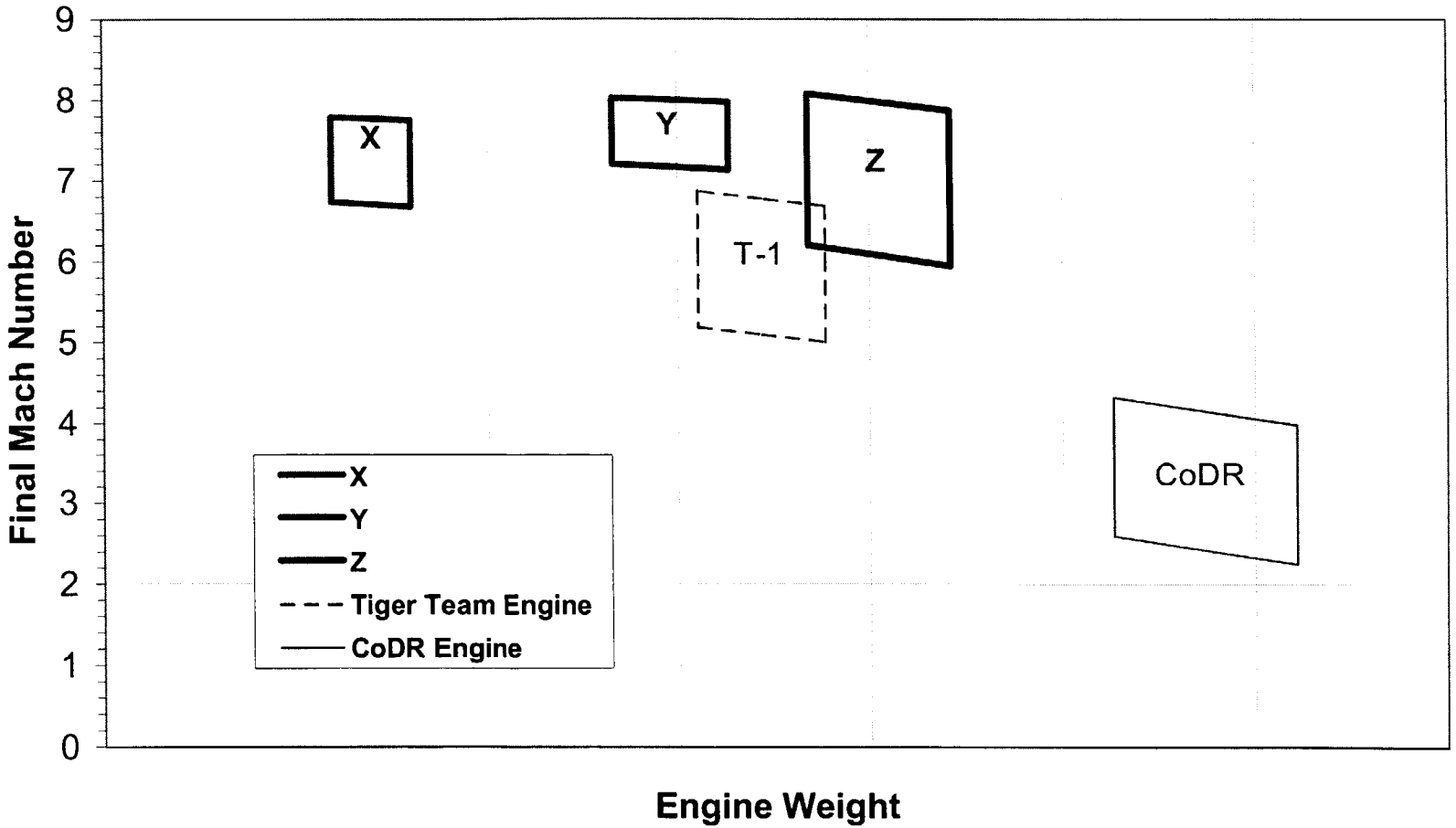
- **Provides NASA with a probability of success, based upon proposed cost and scope**
- **Used at all levels of the project to provide ROM cost estimates for Risks & Opportunities**
- **Developed probability of occurrence for each R & O, at each WBS level**

Monte Carlo Results
Cost / Schedule Assessment Performed



RBCC Engine Selection Results

Final Mach Number - Engine Variants



Summary

- ISTAR project will develop a thermally and power balanced RBCC engine system using JP-7/H_2O_2

- Flowpath selected - proceeding with concept definition activities

- RBC^3 – The power of 3 companies has produced/employed several unique processes
  - Risk & Opportunity Approach
  - Utility Analysis
  - Value Streaming
  - Continuous Risk Management
  - Common Team Tools
  - Purple Team Proposal Approach
  - Joint NASA/Industry Program Planning